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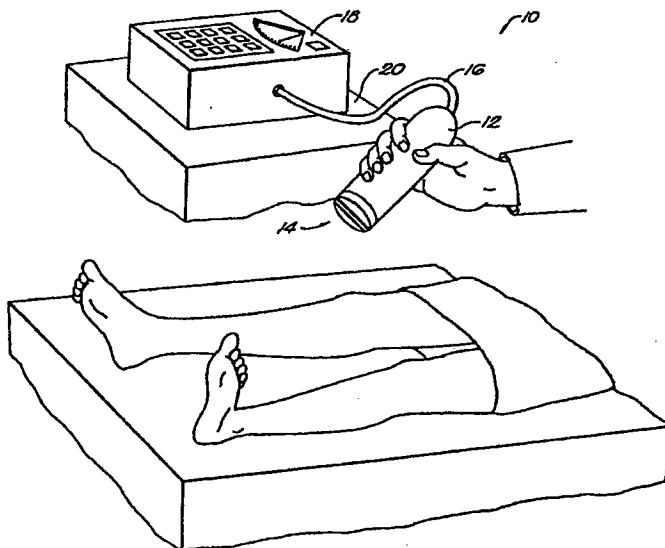
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(54) Title: HAIR FOLLICLE DEVITALIZATION BY INDUCED HEATING OF MAGNETICALLY SUSCEPTIBLE PARTICLES



(57) Abstract

Apparatus, methods, materials and systems for devitalizing hair follicles are disclosed in which magnetically susceptible particles are applied to a skin segment in a manner whereby the particles are deposited within the hair follicles and then subjected to a varying magnetic field to induce localized heating in the proximity of the particle, thereby devitalizing at least one component of the hair follicle to inhibit further hair growth.

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Hair Follicle Devitalization

By Induced Heating of Magnetically Susceptible Particles

Background of the Invention

The technical field of this invention is the removal of hair and inhibition of hair regrowth by devitalization of certain hair structures within hair follicles.

Individual hair follicles comprise a bulb or cavity below the surface of the skin, from which a body of soft keratin is extruded. This shaft of keratin hardens as it passes through the bulb and ultimately protrudes from the skin surface as a "hair." A small cellular structure at the bottom of the cavity, the papilla, together with ancillary germinative structures, is responsible for the extrusion of the keratin which eventually forms into a hair. Permanent hair removal requires devitalization of the papilla or the structures that surround it.

The removal of body hair, a process commonly known as depilation, has been practiced with varying degrees of success for centuries by diverse methods and devices. For example, hot wax can be applied to a skin surface and allowed to harden around body hairs. Once the wax has hardened, it can be removed as a sheet, taking with it those hairs that have been entrapped by the wax. Typically, this is not a permanent process because the removal of the hair shaft does not prevent the regrowth of new hair from the shaft.

Various chemical depilatories have been used to remove hair. Typically these chemical agents are caustic, e.g., sodium hydroxide and the like, which makes the treatment process painful. Moreover, chemical depilatories are often not very effective.

Another approach to depilation is the use of electrical currents to destroy the delicate structures of the hair root. For example, U.S. Patent No. 5,049,148 issued to Mehl discloses an electrical device of this nature. Similar devices, generally known as "electrolysis" devices have been used in various forms, with and without the assistance of chemical adjuvants.

5 However, electrolysis is time consuming because the electrical current must be applied to each hair follicle individually.

10 An alternative approach for permanently impairing regrowth of many hair follicles at once is disclosed in U.S. Patent 5,470,332 issued to Mehl et al. which involves the application of a conductive material to the skin's surface and then applying an electric current to this conductive layer.

15 Most recently, a number of techniques for photocoagulation of the delicate hair structures by laser irradiation have been disclosed. For example, U.S. Patent No. 5595568 issued to Anderson et al., U.S. Patent No. 4,388,924 issued to Weissman, et al., and U.S. Patent No. 5,059,192 issued to Zaias disclose such laser irradiation techniques.

20 In addition, U.S. Patent 5,425,728 and U.S. Patent 5,226,907 issued to Tankovich disclose laser techniques in which the hair follicles on a section of skin are first contaminated with a substance (i.e. carbon particles) that has high absorption of light within a specific frequency band. The skin is then illuminated with such light, typically from a laser source, to heat the contaminating substance and kill the follicles or skin tissue feeding the hair root.

25 None of the processes described above are totally effective in depilating skin. There exists a need for better and more effective techniques. Accordingly, better methods and devices for hair removal would satisfy a long-felt need in the art.

Summary of the Invention

30 Apparatus, methods, materials and systems for devitalizing hair follicles are disclosed in which magnetically susceptible particles are applied to a skin segment in a manner whereby the particles are deposited within the hair follicles and then subjected to a varying magnetic field to induce localized heating in the proximity of the particle, thereby devitalizing at least one component of the hair follicle to inhibit further hair growth.

5 In one aspect of the invention, devices are disclosed which generate a time varying magnetic field and apply such field to a region of a patient's skin that has been treated with magnetically susceptible particles.

10 In one embodiment, the apparatus can include a source of alternating electric current that is applied to one or more coils surrounding at least a portion of a partially open ring-ferrite structure; the structure having an open gap adapted to engage a region of a subject's skin into the follicles of which magnetically susceptible particles have penetrated. Each electrically conductive coil structure is also electrically coupled to a capacitor, such that the coil and capacitance define a resonant circuit, whereby, upon
15 application of an electrical current to the coil, a magnetic field is formed in the gap which heats the magnetically susceptible particles within the hair follicle to induce depilation. The gap can range from about 1 millimeters to about 50 millimeters, more preferably from about 3 millimeters to about 15 millimeters.

20 Various other designs can be employed to deliver the time varying magnetic field to the target hair follicles. The ferrite structure need not be a simple ring but can take alternative geometric shapes designed to concentrate the magnetic field at the desired locus. A plurality of magnetic field guides can also be used. Alternatively, quasi-spherical emitters can be designed to create a similar magnetic field concentration.
25 In addition, ferrite structures can be replaced by other magnetic field guides or concentrators, such as magnetic metallic glasses and ferro-magnetic alloys. In some applications, a simple electromagnetic field generator alone can serve as a source and guide or concentrator to deliver a varying magnetic field to the desired area.

30 In an embodiment described in detail below, the field is generated by a resonant circuit to which a voltage is applied and a driver comprising one or more power transistors is employed to provide electronic impulses in synchrony with the frequency of the resonant circuit, thereby offsetting the energy dissipated by operation. The magnetic field guide (e.g., an open ferrite ring structure) can be readily incorporated
35 into a handpiece which permits the clinician to manually apply the magnetic field to the

5 treatment region. The open ring of ferrite is configured such that the gap is disposed at the tip of the handpiece in order to applied the magnetic field to the target tissue region. The handpiece can further include a coolant to extract the energy which is dissipated as heat with the field guide. The power source, driver electronics, a control
10 microprocessor, manual controls, coolant circulator and various other auxiliary systems can be housed in a remote structure to which the handpiece is connected by one or more cables providing electrical energy and/or coolant and any auxiliary functions to the handpiece.

15 In another aspect of the invention, methods are disclosed to induce hair depilation by magnetic-field heating of magnetically susceptible particles deposited within hair follicles. In one method, the hair shafts in a treatment region optionally can be first extracted by wax treatment and/or tweezers. (An anesthetic agent, such as Novocain can be applied before or after this step.) Optionally or alternatively, the skin can be cleaned to open the patient's pores. A slurry of magnetically-susceptible
20 particles is then applied to the treatment region in a manner that facilitates deposition of such particles in to the empty spaces of the hair follicles. Deposition into the follicles can be accomplished simply by manual rubbing, or with the aid of mechanical or pressurizing instruments. (For example, a vibrating applicator (e.g. an ultrasound applicator operating at about 10 – 20 kHz) can be used or a pressurized fluid (liquid or
25 gaseous) carrying such particles can be applied to a sealed region.)

Following application of the particles and deposition of such particles into the hair follicles, the skin surface can be cleaned of any excess particles or applicator fluid. The treated region is then ready for application of the alternating magnetic field. The
30 time-varying field induces localized heating of the particles, a portion of which will be located near enough to the papilla or other delicate structures to devitalize the hair follicle. It may also be desirable to heat the patient's skin (or monitor the skin temperature) to reduce the amount of energy that the particles need to deliver in order to kill the cells of the follicle.

5 The particles can then be removed (or left to be naturally cleared or metabolized by the patient's body). The use of iron oxide particles is particularly advantageous because such materials have very low toxicity and can be absorbed by the body and used as nutrients. When removal is desired, mechanical suction, aided by vibration or intermittent flushing (e.g., with water, saline or other solvents), can be employed.
10 Alternatively, magnetic forces can be applied to extract the magnetic particles.

 Such methods can further include the step of protecting any sensitive metallic implants or prostheses before the application of the magnetic field. For example, dental fillings or metal orthodontic braces may interfere with the removal of facial hair. Such
15 structures can be protected by one or more mouth guard-type insulators which are fitted to surround any metallic dental work. The mouth guard is preferably flexible and comprises a material that possesses high magnetic shielding properties. For example, the mouth guard can be made from a plastic coated steel (or other metallic conductor).

20 In yet another aspect of the invention, compositions are disclosed for effecting magnetic field heating of hair structures to induce depilation. The compositions include magnetically susceptible particles having an average size sufficiently small to allow penetration of at least a portion of said particles into the follicles on the target skin segment and further having sufficient magnetic properties to induce localized heating in
25 the presence of variable magnetic field following penetration into the hair follicle to devitalize at least one component of the hair follicle and thereby inhibit further hair growth from within the follicle.

 The compositions can include a slurry of particles having an average particle
30 size ranging from about 5 Angstroms to about 100 micrometers in diameter, or more preferably ranging from about 50 Angstroms to about 10 micrometers in diameter. The compositions can further include particles of a lubricant material, such as surfactants, or the particles can be coated with a lubricating material, such as a surfactant, or silicone, hyaluronic compositions, dextran or combinations thereof. Such compositions can be
35 delivered to the skin as either dry slurries or as part of fluid delivery compositions.

5 Fluid delivery compositions according to invention can further include a fluid carrier that enhances penetration of the particles into the hair follicles. The fluid carriers can be lotions (e.g., aqueous or non-aqueous liquids or liquid solutions, as well as emulsions, suspensions) or gaseous mixtures. Liquid lotions can include surfactants, pore opening agents or transdermal penetrating enhancing agents. Gaseous carriers can include air or other gas mixtures, typically applied to the skin under pressure to drive the magnetically susceptible particles into the skin pores and, in particular, into the lower regions of the hair follicles. Gels or semi-solid materials, such as polyvinyl alcohols, which soften or liquefy under application pressure can also serve as a delivery medium for the particles.

15 In yet another aspect of the invention, systems or kits are disclosed for depilating hair, including compositions for effecting magnetic field heating of hair structures to induce hair depilation and one or more of the following components: topical anesthetics, wax compositions for hair extraction, apparatus for applying a variable magnetic field to a skin region, particle/lotion applicators, penetration enhancing devices, particle removal devices and protective shield-structures.

25 The magnetic field generating apparatus can include a source of alternating electric current, a partially-open ring-ferrite structure; the structure having an open gap adapted to engage a region of a subject's skin and permitted an electrically conductive coil structure surrounding at least an portion of the ferrite structure and electrically coupled to the source of alternating current through a capacitance, such that the coil and capacitance define a resonant circuit, whereby, upon application of the compositions containing magnetically susceptible particles to hair follicles within the skin region and the application of an electrical current to the coil, a magnetic field is formed in the gap which heats the magnetically susceptible particles to induce depilation.

35 The terms "depilation" and "devitalization" as used herein are intended to encompass the devitalization of hair follicles, the destruction of hair papilla (and/or associated structures), inhibition of future hair growth, or interference with any portion of the normal hair cycle. The process of depilation as taught in the present invention

5 describes a variety of hair removal processes included, *inter alia*, the destruction (or substantial deactivation) of hair papilla and/or the epithelium columns that connect a growing or mature hair to the papilla; closure or modification of the hair follicle to preclude hair foliation; as well as simply the removal of the hair from the follicle. Such depilation or devitalization processes can be directed to single hair follicles or,
10 preferably to larger areas of skin to treat a region including more than one follicle, it being understood that depilation or devitalization over any region of skin may only be partially successful during an initial treatment according to the invention and a plurality of treatments may be necessary to obtain a desired result of general hair removal from a region of a subject's body.

15 The term "magnetically susceptible particles" as used herein is intended to encompass a wide range of either magnetic or electrically conductive materials, which are of a size that permits their passage into hair follicles. The magnetic or electrically conductive materials which can be used herein include any non-toxic metal, including
20 gold, silver and palladium, as well as magnetic metals such as iron, nickel and cobalt and their alloys, other conductive or magnetic metal alloys and metallic compounds which likewise possess electrical or magnetic properties. One such compound, magnetite, a magnetizable iron oxide having the general formula of Fe_3O_4 , has proved to be particularly useful in experimental trials, but various other materials may prove to
25 be more advantageous or useful for particular applications. The term "magnetically susceptible particles" encompasses not only materials that are inherently magnetically susceptible but also materials which become magnetically susceptible when deployed in the *in vivo* environment. The particles can be as small as individual molecules or ions. For example, spin transition polymers currently being developed for ultra dense
30 magnetic memory devices may be useful. On exemplary compound magnetically susceptible particles can have the general formula: $\text{Fe-R-I} \cdot n\text{H}_2\text{O}$, where R is ariazol, I is a cation or anion and $n\text{H}_2\text{O}$ is noncoordinated water.

35 Typically, the average size (i.e., the diameter or length of the longest dimension for non spherical shapes) of the magnetically susceptible particles can vary from about 5

5 Angstroms to about 100 micrometers, and more preferably from about 50 Angstroms
to about 10 micrometers. The magnetically susceptible particles can be applied to the
skin as a powder, in a liquid or as part of a lotion. Within a particular powder, liquid or
lotion the size of the particles can range by more than one, or even two, orders of
10 magnitude; the only critical factor being that a sufficient number of the magnetically
susceptible particles should be capable of entering the hair follicle cavity and lodging in
positions that facilitate depilation.

15 The term "magnetically-susceptible particles" is also used herein to encompass
coated particles as well as molecular structures that incorporate any of the above
referenced elements or compounds. Coating materials can include surfactants,
polysaccharides, such as dextran, as well as ficolls, silicones, chondroitin sulfates,
dextrane sulfates, laurates, inulins, and xylans. Molecular structures can include
ferritins, hemosiderins and similar materials which comprise a spherical protein cage in
which iron is stored (e.g., in the form of iron(III)oxyhydroxide). Colorants can also
20 form part of the particles.

25 A presently preferred embodiment comprises a coated magnetite powder. Such
powders are available from a variety of sources. For example, magnetite powders are
available from Ferrofluidics Corporation (Nashua, New Hampshire) and/or Toda
America Incorporated (Schaumburg, Illinois). As noted above, the average size of
individual magnetite particles can vary in size from about 10 angstroms to about 100
micrometers in diameter. The initial susceptibility of such particles ($4\pi M/H$) can range
from about 0.1 to 0.9 EMU/gauss/gFe.

30 It should be appreciated that the formula Fe_3O_4 for magnetite is an empirical
formula. Magnetite is more precisely described as a crystalline metal oxide having two
components: FeO and Fe_2O_3 . Two different valence iron ions occupy specific sites in
the crystal structure. The A metal is Fe^{+2} and the B metal is Fe^{+3} . The arrangement
causes a transfer of electrons between the different irons in a structured path or vector.
35 This electric vector generates the strong magnetic field associated with native magnetite

5 ores. Although magnetite is a presently preferred material for the magnetically susceptible particles of the present invention, various other materials may also be useful, including, for example, iron hydroxides, cobalt- Fe_3O_4 , barium ferrites, and metallic iron particles.

10 Superparamagnetic particles (e.g. with initial susceptibilities greater than 0.5 EMU/gauss/gFe and/or negligible coercivity) can also be used. One such composition, a gamma ferric oxide, is disclosed in U.S. Patent 5,411,730 issued to Kirpotin et al on May 2, 1995 and incorporated herein by reference. This patent also describes various techniques for coating particles to form ferroliposomes and the like which can be
15 generally applicable to the present invention.

Colloidal suspensions of magnetite, coated with one or more surfactants, are also available from Ferrofluidics Corporation. More generally, suspensions of magnetically-susceptible particles can be formed with water, water/alcohol mixtures or
20 multiphasic liquids as the carrier. Suspensions useful in the present invention can vary in viscosity from about 1 centipoise to about 100,000 centipoise with magnetite concentration varying from about 0.5 volume percent to about 20 volume percent (yielding magnetic flux densities from about 20 gauss to about 1,000 gauss). One exemplary composition can be formed by coating magnetite particles with a cationic
25 surfactant and suspending such coated particles in a water/ethanol mixture. In other applications, anion, amphoteric or non-ionic surfactants may be preferred.

Lotions useful in the applying the magnetically susceptible particles to the skin can include aqueous and/or organic (e.g., oily or alcohol) fluids, as well as emulsions
30 having both aqueous and non-aqueous phases. The lotions are preferably chosen because of their ability to promote penetration of the magnetically susceptible particles into the cavities of the hair follicles. In some applications a proper balance of hydrophobic and hydrophilic components may be optimal in assisting penetration. In other applications the addition of an electrically charged component or the presence of
35 chemical additives with chemical moieties that present a surface electrical charge can be

5 useful. In yet other embodiments, it can be useful to employ lubricants such as silicones or hyaluronic compositions, either as coatings for the particles or as additional components of the lotion to enhance lubricity. Alternatively, chemical agents that induce expansion of the hair follicle openings can be useful.

10 Thus, the term "lotion" as used herein is intended to encompass solutions, such as aqueous and organic solvent solution and well as suspensions, emulsions and the like which serve as carriers for a magnetically susceptible particle or plurality of such particles. In one embodiment the lotion can be an aqueous solution including a surfactant. In another embodiment, the lotion can be a mixture of water and alcohol or
15 a mixture of water and aliphatic liquid. Alternatively, the lotion can be an oil alone or in conjunction with an emulsifying agent that ensures a uniform distribution of magnetically susceptible particles. The lotions can further include colorants, transdermal enhancing agents, as know in the art, and pore opening agents, likewise known in the art, to facilitate hair follicle penetration.

20 In the present invention, the application of the varying magnetic field to the magnetically susceptible particles induces rapid and extremely localized heating in the region of immediately surrounding the particles. Although no one theory of explanation may be entirely correct in analyzing this heating effect, it appears that the orientation and reversal of domain polarities in magnetic materials as well as the creation of eddy
25 currents in conductive materials both play a role in the superheating of the particles. When a particle is disposed within the hair follicle, the heat generated by the particle is sufficient to destroy or devitalized the follicle's internal structures necessary for hair growth.

30 "Alternating current" as used herein is intended to encompass not only sinusoidal waveforms, but also various other waveforms, such as pulsed, square wave, ramped, saw tooth, chirped waveforms and the like. The particular shape of the waveform is largely irrelevant so long as it can induce a variable magnetic field in the
35 target skin region where magnetically susceptible particles are heated to achieve the

5 desired depilatory effect on hair follicles. Similarly, the term "variable field" is intended
to encompass not only reversals of polarization but also pulsed fields and any other
magnetic field that changes over time in a manner that permits the transfer of energy
from the power supply to the magnetically-susceptible particles. The frequency of
10 alternation or variation can vary from about 1 kilohertz to about 10 gigahertz,
preferably from about 10 kilohertz to about 100 megahertz, and, in some applications,
it may be preferable to vary the frequency from about 20 kilohertz to about 20
megahertz or from about 50 kilohertz to about 3 megahertz.

15 Ferrite cores useful in channeling magnetic field lines can be obtained from
various sources including Magnetics, Inc. (Butler, PA); TDK Corporation (Tokyo,
Japan) or U.S. Philips Corporation (New York, New York). Ferrites useful in the
present invention encompass ferromagnetic compounds and iron-containing
compositions generally (including ferromagnetic alloys and magnetic metal glasses)
which exhibit high magnetic permeability and also high electrical resistivity. One
20 example of such materials is the 3F3 Ferrite manufactured by U.S. Philips Corporation.
The ferrite preferably is capable of generating a magnetic field of at least 0.02 Tesla
and, more preferably, a field greater than about 0.3 Tesla. In some applications a ferrite
core may not be necessary and instead can be replaced by an air coil (e.g. a torroidal
coil) or other arrangements that can serve as magnetic field guides.

25 The term "Curie temperature" or " T_c " as used herein is used as a measurement
of temperature (or temperature range) where magnetically susceptible materials
undergo a rapid change in their properties. For many of the magnetically susceptible
materials useful in the present invention it represents a plateau point beyond which
30 additional exposure to the variable magnetic field will not induce significant additional
heating effects. In applications where a lotion containing a substantial quantity of
magnetically susceptible particles is applied and penetrates into the skin, it is desirable
that the particles themselves exhibit a high enough Curie temperature to devitalize the
follicle by local heating effects but not induce significant thermal damage to
35 surrounding dermal structures. In some embodiments of the present invention, the

5 Curie temperature of the magnetically susceptible particles useful in the present invention is preferably greater than about 45°C, more preferably greater than about 60°C, and most preferably greater than about 75°C, but less than 600°C.

10 However, in other applications of the invention where the heating is very localized, the Curie temperature of the particles can be much greater, so long as the total application of depilating energy does not have significant adverse effects on surrounding tissue regions. Magnetite is an example of a very high Curie temperature material that is, nonetheless, particularly useful in certain applications of the invention.

15 The invention will next be described in connection with certain illustrated embodiments; However, it should be clear that various changes and modifications can be made by those skilled in the art without departing from the spirit and scope of the invention.

20 **Brief Description of the Drawings**

The invention may be more fully understood from the following description when read together with the accompanying drawings in which:

FIG. 1 is a schematic illustration of a system according to the invention for magnetic devitalization of hair follicles in a skin segment;

25 FIG. 2 is a more detailed cross-sectional schematic illustration of an apparatus for delivering a varying magnetic field according to the invention;

FIG. 3 is a schematic diagram of a driver circuit for the apparatus of FIG. 2;

30 FIGS 4A - 4E illustrate a method of hair follicle devitalization according to the invention; FIG 4A shows an optional initial step of removing hairs from a skin surface; FIG. 4B illustrates the application of magnetically susceptible particles to the skin surface; FIG 4C illustrates the migration of magnetically susceptible particles into the hair follicles and the removal of any excess magnetically susceptible particles and/or carrier fluid from the skin surface; FIG. 4D shows the application of a varying magnetic field to induce heating of the particles; and FIG. 4E illustrates the optional further step of removing the particles from the follicles following treatment;

35 FIG. 5 illustrates an apparatus for applying magnetically susceptible particles to follicles in a skin segment;

5 FIG. 6 illustrates an alternative apparatus for applying magnetically susceptible particles to follicles in a skin segment;

 FIG. 7 illustrates another alternative apparatus for applying magnetically susceptible particles to follicles in a skin segment;

10 FIG. 8 illustrates an apparatus for removing magnetically susceptible particles from follicles in a skin segment;

 FIG. 9 illustrates an alternative apparatus for removing magnetically susceptible particles from follicles in a skin segment; and

 FIG. 10 illustrates a protective cover for dental work when removal of facial hair is desired.

15 Detailed Description

 In FIG. 1, a system 10 for magnetic follicle devitalization is shown comprising a handpiece 12 which houses a magnetic field generating open-ring ferrite structure. The open-ring is oriented such that the opening in the ring forms a gap 14 at the distal end of
20 handpiece 12. The handpiece is connected via conduit 16 to a controller 18 and an auxiliary housing 20 (which can include driver electronics, a control microprocessor, manual controls, a coolant circulator and various other auxiliary systems).

 In FIG. 2, the handpiece 12 of FIG. 1 is shown in more detail including the ferrite
25 ring structure 30, an inductive coil 32 which is wrapped around the ferrite core and a capacitor and/or other electronics 35. Power to generate a magnetic field within the ferrite 30 can be supplied from the housing 20 (shown in FIG. 1) via electrical cables 40. The handpiece can also incorporate an internal cooling chamber 34 which is supplied with coolant via a coolant source conduit 36. The coolant circulates within the chamber 34 to
30 extract heat which otherwise would build up in the ferrite ring 30. Heated coolant can be withdrawn from the handpiece via a coolant exit conduit 38 for recycling within the housing or disposal. The electrical cables as well as the coolant supply and extraction conduits can all be encased within a single tubing 16 (or, alternatively, separate cables can be employed for electrical power and coolant delivery). The shell 28 or rim 29 of the
35 handpiece 12 can also be used to heat the patient's skin. The rim 29 can also include a marker mechanism (e.g., an ink application) 27 which serves to delineate areas which have been treated.

5 The electronic circuitry 35 within the instrument (in cooperation, if necessary, with an auxiliary processor within housing 20) can also include an electronic sensor for metallic implants such as dental work (e.g., metallic fillings and/or orthodontic braces) that may need to be protected if the treatment region is in close proximity to such an implant.

10 In FIG. 3, an electrical schematic diagram of a driver circuit for the magnetic field-generating ferrite ring 30 is shown comprising the inductive coil labeled "L₁" in the drawing. As shown, it consists of 6 turns of wire about the ferrite torroid 30 (shown in phantom). The inductor L₁ is connected to capacitor C, as shown, and supplied with a
15 current via a center tap. Power transistors T₁ and T₂ serve to inject additional energy into the circuit as energy is lost (as heat) in the ferrite core 30 and/or other components of the circuit. In one illustrative embodiment, about 2 amperes is supplied via choke L₂ to the center tap. The choke L₂ can have an inductance of 350 microhenries and the 6
20 turn inductor L₁ can have an inductance of about 3.5 microhenries. The capacitor C can have a capacitance of about 0.08 microfarads. Power transistors T₁ and T₂ are N-channel MOSFET transistors (Model No. IRFP460LP) available from the International Rectifier Corporation.

25 Together the inductance L₁ and the capacitors C form a resonant circuit with approximately 70 amperes of current flowing back and forth. Preferably, the resonant circuit of the coil L₁ and capacitance C has a Q factor over 10. The opening and closing of transistors T₁ and T₂ are timed to synchronize with the resonant frequency of the LC circuit. The ferrite core can be a open-toroidal structure (with a gap of about 7 mm) made, for example, from 3F3 ferrite material available from the U.S. Phillips Corporation.
30 This current-fed resonant push-pull circuit serves to generate an oscillating magnetic field within the ferrite ring 30 (and across the gap) at the same frequency as the resonant LC circuit.

35 All matter exhibits magnetic properties when placed in an external magnetic field. Even non-magnetic metals, such as copper and aluminum, are affected by the presence of a magnetic field. Materials that are attracted to the pole of a magnet are classified as paramagnetic, while those that are repulsed are classified as diamagnetic. Materials, such as iron, that exhibit a very strong attraction towards the pole of a magnet are further classified as ferromagnetic. Whether a substance is paramagnetic or diamagnetic depends

5 primarily on the presence or absence of free magnetic dipole moments in the material's constituent atoms.

10 Because paramagnetic materials have free magnetic dipole moments, the presence of a magnetic field will induce alignment of the normally randomly aligned moments (or domains) of the material. When an alternating magnetic field is applied to such materials, the dipoles will attempt to reverse their orientation. As the dipoles are cycled back and forth, heating occurs at the microscopic level until a certain temperature (dependent on the material) is reached. This temperature is typically referred to as the Curie temperature and represent a plateau for many materials at which they exhibit minimal responses to further magnetic excitation.

15 In one embodiment the present invention can take advantage of this property of magnetically susceptible materials by "tuning" the frequency and duration of the varying magnetic field to ensure that the magnetically susceptible particles are rapidly brought to their Curie temperature and held there only for a period of time sufficient to induce apoptosis of the hair papilla and/or other hair structures.

20 In another embodiment of the invention, heat is generated by interaction between the magnetically susceptible particle and a fluid carrier. When such a magnetically susceptible particle is exposed to an alternating or rotating magnetic field while it is in a fluid, the particle will be induced to rotate or swing into alignment with the field. The mechanical friction between the particle and the fluid dissipates the field energy as heat in fluid surrounding the particle. The optimal frequency for heating will depend upon the particle's magnetic movement, its moment of (rotational) inertia and, to some extent, the viscosity of the surrounding fluid. At frequencies above the optimal frequency (for a particular particle and fluid composition) the moment of inertia for individual particles will inhibit heating because the particles will be unable to swing in response to such high frequencies.

25 30 35 FIGS. 4A-4E illustrate a method of hair follicle devitalization according to the invention. In FIG. 4A, hair shafts 41 are removed from the lumens or cavities 42 of hair follicles. The hair shafts 41 can be removed, for example, by the application of a hot liquid wax 44 and, after solidification, removal of the wax 44 from the patient's

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/02166

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 A61N1/40

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 A61N A61F A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 400 940 A (LEVEEN HARRY H) 5 December 1990 (1990-12-05) column 10, line 5 - line 20 column 11, line 32 - line 37 column 15, line 4 - line 25; claim 1 column 20, line 6 - line 41; figures 26,27	1-6,35, 38,40,71
Y	---	7,8,39
X	FR 2 634 129 A (GRUP JUNE SCP) 19 January 1990 (1990-01-19) page 5, line 30 - page 6, line 23; figure 4	1,35,71
Y	---	7,8,39
	--- -/--	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

18 May 1999

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

International Application No
PC, US 99/02166

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 87 03798 A (MIRELL STUART G) 2 July 1987 (1987-07-02) page 8, line 20 - line 27; figure 1	1,35,71
A	---	17
A	US 5 197 940 A (SIEVERT CHESTER E ET AL) 30 March 1993 (1993-03-30) column 6, line 6 - line 12 column 9, line 4 - line 11 column 10, line 31 - line 61; figures 5,6	1,20,35, 40,71
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 99/02166

Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.: 21-34
because they relate to subject matter not required to be searched by this Authority, namely:
Rule 39.1(iv) PCT - Method for treatment of the human or animal body by therapy
2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-20, 35-40, 71, 76

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

1. Claims: 1-20, 35-40, 71, 76

An improved magnetic field generator adapted to engage a region of skin

2. Claims: 41-70, 72-75

A composition comprising magnetic particles sufficiently small to penetrate the skin as well as means for handling the particles

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PC., US 99/02166

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